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LIFE IN SPACE - NEW ADVANCES IN SPACE BIOLOGY

An Interview with H. Bücker

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LIFE IN SPACE - NEW ADVANCES IN SPACE BIOLOGY

An Interview with H. Bücker,
Chairman of the Study Group for Biophysical Space
Research, Frankfurt am Main

ABSTRACT. The sensational results of scientific research in space have not only given new force to the old question of traces of life on other celestial bodies, but have led especially to studies of how living organisms - from bacteria to man - are influenced by the conditions of space. We have interviewed the Chairman of the Study Group for Biophysical Space Research at Frankfurt am Main, Priv.-Doz. Dr. H. Bucker, concerning the present state of knowledge in this field.

UMSCHAU: Dr. Bucker, during recent years a new research field called "space biology" has acquired increasing importance. What is understood by that term, and what are the objectives? /2*

BUCKER: Space biology is to be understood as extraterrestrial biological research. Two lines of research may be distinguished here, namely on the one hand the effect of the various factors in space on biological organisms, and on the other the search for life in the cosmos.

UMSCHAU: How can the much discussed question "Is there life outside the earth?" be answered in the light of present knowledge?

BUCKER: Before we say anything on that subject we must agree on what we mean by "life." If substances of high molecular weight which can duplicate themselves are to be referred to as "living," I fully believe that the possibility of such lowest forms of life exist in our solar system. If on the other hand we are thinking of higher life, say of animals and plants, then our solar system can be eliminated with a fair degree of certainty. The earth appears to play a unique role here. For the entire universe, however, there is a certain probability that higher life also exists, since we may assume for many other fixed stars the presence of a planetary system, and that is what is required to afford the conditions for organic life as we understand it.

Space Factors: Radiation and Weightlessness

UMSCHAU: One of the problems with which extraterrestrial biophysics is concerned is the study of how space affects living organisms. The first consideration here is radiation - protons, electrons, and heavy particles. What effects have been observed on the astronauts during the Gemini flights? /3

**Numbers in the margin indicate pagination in the foreign text.*

BUCKER: Yes, radiation is an important factor. We'll come back to that later.

As you know, up to now manned space flights have only been carried out at a low altitude, beneath the radiation belt. For that reason the dosage has been quite low, some 8-16 mrad/day, and is still within the permissible dosage on the earth. For that reason no effects of radiation on the astronauts have been observable.

Another thing was discovered, however. About 90% of the soft proton dosage that the astronauts were exposed to came from the South Atlantic anomaly of the radiation belt. This is caused by an anomaly of the magnetic field of the earth, the hypothetical dipole being shifted by 340 km with respect to the center of the earth. For that reason the mirror point of the radiation belt extends very deep into the earth's atmosphere in the South Atlantic. While the radiation dosage during flight through the South Atlantic anomaly is still within the permissible limits, there is a chance here to study what effects show up when flying through the radiation belt.

UMSCHAU: What is your opinion of the radiation hazard in the case of a moon flight, when of course the radiation belt around the earth must be crossed? What radiation influences must the astronauts reckon on on the moon after they land?

BUCKER: In crossing the radiation belt during a moon flight doses might occur of the order of magnitude of several rads. The maximum inside a Gemini capsule, i.e. in other words behind a shield 2 g/cm^2 in thickness, will be about 100 rad/day, but no harmful effects are to be expected, since the radiation belt is passed through in a relatively short time. But let me say for purposes of comparison that here on the earth we reckon with a maximal allowable radiation dose of 0.3 rad/week. /4

In appraising the effect of radiation we must also take into account the fact that the spectral composition of the solar and also of the galactic radiation is quite different from that of the rays that we use here on the earth. In the radiation belt we have a very high proportion of soft radiation. This gives a very high surface dose, but a very low depth effect.

Then after the radiation belt has been passed, the other two components of the radiation come into play, namely solar and galactic radiation. Galactic radiation provides a constant radiation component which is between 10 and 30 mrad/day. This radiation is very hard, very penetrating; a radiation shield is practically impossible. To this must be added the fact that the heavier particles in the cosmic radiation make an especially high contribution to the biological effect.

UMSCHAU: How many days can the astronauts spend on the moon without suffering radiation damage? Solar flares must represent a special danger. Can a flare warning service perhaps be arranged there?

BUCKER: As far as galactic radiation is concerned the length of the astronauts' stay on the moon is unlimited. Solar flares, on the other hand, represent a serious danger, especially as they cannot be predicted long in advance. When a flare breaks out on the sun it is observable on the earth after eight minutes on the basis of the electromagnetic radiation (especially the H alpha line). High-energy protons enter the earth's orbit after 30 minutes after the outbreak of the flare; low-energy protons require up to 24 hours for their trip to the earth. The time span remaining for warning of high-energy protons thus amounts to about 20 minutes. Within that short time, then, so-called /5 "space walks" must be broken off. On the moon the astronauts must within that 20 minutes get back into the lunar landing apparatus and try to get back into orbit around the moon in order to take refuge in the Apollo capsule. While the whole maneuver will last longer than 20 minutes, so that the astronauts receive the radiation spearhead of the flare, the protective effect in the Apollo capsule is still considerable, since the greatest part of the radiation dose does not occur for several hours.

UMSCHAU: The supersonic and hypersonic commercial planes that will go into service during the next ten years are supposed to fly at heights of 20 km and more. What radiation effects will passengers on these planes have to expect? This question is of course of special importance to the plane crews.

BUCKER: This is indeed a problem. At 20 km the flying altitude of the future supersonic planes is in the maximum of the secondary ionization of the galactic radiation in the earth's atmosphere. A second possible danger here again is due to solar flares, which may play a part that cannot be overestimated, especially in the case of polar routes. These are protons in the range of energy of some thousands of Mev's, with a very high soft component, which is deflected by the earth's magnetic field in equatorial latitudes, but not at the poles. Here again we must reckon on doses of several rads. For that reason consideration is being given to extending the flare warning system for the moon-landing mission to supersonic air traffic as well.

UMSCHAU: Is there reason to expect any changes in the outer skin of space ships or planes due to radiation?

BUCKER: If you mean by that material fatigue effects and modifications of the crystal lattice, the answer is no, for the radiation intensities are too low /6 for that. On the other hand radioactive radiations may be induced on the surface by nuclear transmutation, so that caution is required especially in maintenance work on the ground.

UMSCHAU: Another peculiarity of flight in space is the state of weightlessness. Are any effects on the human organism to be expected from that cause?

BUCKER: That problem is still by no means cleared up. In particular the possibility must be investigated that some effects may be strengthened or weakened by the combination of weightlessness and exposure to radiation.

It can be said with some confidence that a demineralization of the bones comes about through weightlessness. This demineralization was significantly greater in the Gemini astronauts than in a group of control subjects who maintained absolute bed rest during the same time.

Another effect of weightlessness consists in the fact that orientation difficulties arise, especially when optical orientation is rendered difficult or impossible. This case may e.g. occur in darkness in the space vehicle or if the eyepieces are misted over. It was reported for example that in one of the American space walks the ventilation of the space suit was not adequate. This caused the front window to fog over at eye level. The astronaut became slightly disoriented on that account and got into a heightened state of excitement. This resulted in increased perspiration, so that the visual conditions were still further impaired.

Satellite Experiments /7

UMSCHAU: The American Biosatellite II exposed various plants and animals to the effects of radiation and weightlessness in space for several days. Wheat germs are reported to have grown faster than on earth. As was to be expected, the growth of roots and leaves was unoriented; i.e. the roots e.g. grew upward. What new knowledge was gained from this biosatellite experiment?

BUCKER: The main purpose of that series of experiments was to investigate the effect of weightlessness and the combined effect of weightlessness and radiation on various living organisms. In order to intensify this combined effect, a radioactive radiation source containing strontium^{90} was installed in the Biosatellite. It is true that a completely unoriented growth was found in the plants, and this provided a confirmation of the fact that the oriented growth on the earth (roots downward) is to be attributed largely to gravity.

UMSCHAU: Various insects and beetles also flew with the Biosatellite II. What peculiarities were observed in these animals?

BUCKER: The flour beetle *Tribolium* was packed into the Biosatellite II as an animal subject.

UMSCHAU: What scientific laboratory experiments on this complex of problems are being carried out in Germany?

BUCKER: Biological experiments are being prepared in the Federal Republic of Germany that are to be carried as part of the payload in satellites. Thus for example Dr. Lotz of the Zoological Institute of the University of Frankfurt is carrying out an experiment with leeches. They are to be exposed to the effects of weightlessness in a satellite for up to a year.

We in our study group are using a different subject, namely photogenic bacteria. They have the advantage that the glowing is readily measurable and can be transmitted by radio to the earth as a positive indication of their viability.

But before these payloads are packed into a satellite, experiments should first be done with high-altitude rockets. We are a little sorry that the German satellites are mainly reserved for physical researches and that all the places on them are booked up. But we hope to be able to get a place on an American satellite in the next few years.

At the Institute for Aerobiology Dr. Petras has exposed bacteria in high-altitude rockets to the effects of ultraviolet radiation and vacuum. He found that a vacuum has only a slight effect, but that ultraviolet radiation has a very destructive effect on the bacteria.

Laboratory Experiments on the Ground Simulate Space Conditions

UMSCHAU: Are there living organisms in space or on other planets that could for example be transported to the earth? You have carried out vacuum experiments on this question in order to determine whether a microorganism could be transported from one planet through space to another planet. What was the result of these experiments?

BUCKER: The point of our investigations was to determine whether the vacuum /8 of outer space possibly represents a barrier to the transport of living organisms. It has long been known that e.g. bacteria can survive even in an extreme vacuum. As a test we investigated the desorption in an extreme vacuum, or in other words how many molecules if any were given off from the surface of the bacteria. It was found that more than anything else the loss of water plays a decisive role in the survival of the bacterium. The rapidity of the loss of water was found to be a decisive factor. The rapidity with which the vacuum is increased also plays a part. We are now carrying out investigations to determine whether bacteria can survive slow evacuation which are killed by rapid evacuation.

UMSCHAU: Do these investigations afford any basis for deciding whether it is necessary or even sensible to sterilize space vehicles before sending them to other planets?

BUCKER: Yes, it is known that spores of bacteria or fungi are present at great altitudes, say 40 km up. It would thus be possible for rockets sterilized on the ground to get contaminated again in flying through those strata.

UMSCHAU: If we assume that a microorganism resists both the vacuum and the radiation of space, how can we imagine such a particle's leaving the field of gravity of one planet and so getting to another planet?

BUCKER: A particle, such e.g. as a bacterium or a virus, is exposed on a planet to various forces, -- first gravitation, second radiation pressure, and finally thermal molecular motion. If we take account of all these factors and calculate them, we come to the conclusion that it is extremely improbable that a bacterium can leave the gravitational field of one planet to travel through /9 space and arrive at another planet. It is therefore practically impossible for particles such as bacteria from the earth's atmosphere to get into free space and so possibly reach other planets. The answer to the question is different with respect to planetoids of e.g. only 100 or 200 km in diameter. There might be such a possibility there. But that would still only mean that microparticles could get from very small celestial bodies into space, and not the other way around, say from the earth.

Limitations of Space Travel

UMSCHAU: Radiations of various kinds set certain limitations as to range for manned space flight projects, because at the high speeds necessary new effects come into play. I am thinking here particularly of the "proton barrier" and the Doppler effect, which because of the increasing acceleration causes ultraviolet light to strike the space ship as X-ray radiation. Where are the limits, and how far can a manned space ship go, in view of these effects?

BUCKER: First of all we must realize that in the present state of the art the accomplishment of such interstellar flights does not appear possible.

You know, of course, that interstellar space is not empty, but contains protons in a concentration of about one particle per cm^3. We have seen that proton radiation exerts a biological effect. Now it is theoretically a matter of indifference whether the protons are in motion and strike against a stationary object or whether the protons exhibit only a slight motion and an object is moved at great speed through this proton suspension. What matters is only the relative velocity of the protons and the object. If the space ship attains, say, one quarter of the speed of light, i.e. 75,000 km/sec. /10
the protons striking against it cause a radiation in the order of magnitude of 10,000 Mev. That corresponds to the speed of a quite respectable particle accelerator (teleproton synchrotron about 30,000 Mev). By analogy to the sonic barrier or the thermal barrier we thus encounter a "proton barrier" at 1/4 the speed of light.

If we should ever get past this barrier, not far below the speed of light we should come to another limit, which is imposed by the Doppler effect, but this barrier is rather of theoretical than practical interest. Because of the great velocity the light of the stars is shifted to shorter and shorter wavelengths, so that finally the space vehicle is exposed to an X-ray radiation.

But even the "proton barrier" at one quarter the speed of light poses problems of protection against radiation that are hardly to be solved at the present state of the art. At the high relative velocity of space ship and protons the impact produces secondary effects, neutrons, X-rays, etc., which can hardly be screened out at reasonable expense.

UMSCHAU: And how far would a space ship get whose speed -- given the technological possibility of that -- approached the proton barrier?

BUCKER: At about 1/4 the speed of light the biological time gain due to the slower rate of all vital processes is of the order of magnitude of 1%. But the increased exposure to radiation at the proton barrier would cancel out this time gain, since the life of men would be shortened by the effect of the radiation.

We might therefore argue somewhat as follows: 1/4 the speed of light represents the real, ultimate limit that we can ever achieve. That means that in four years we travel the distance of one light year. The nearest fixed star, Alpha Centauri, is four light years away from our solar system. To reach it would thus take a voyage of at least 16 years and the return voyage would last just as long. Even if men determined to make such a voyage, it can still be stated that the nearest fixed star, Alpha Centauri, represents the absolute limit of manned space travel.

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